2017 EKG Workshop
Advanced

Family Medicine Review Course
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Part II - Objective

• Describe a useful approach to interpreting “challenging EKGs”
• Discuss some advanced EKG concepts through cases
• Demonstrate how to systematically apply the basic principles of EKG interpretation to uncover interesting and/or significant EKG findings
Disclosure

• The speaker has nothing to disclose
Approach to EKG Interpretation

- Rate
- Rhythm
- Axis
- Intervals (PR, QRS, QT)
- Chamber sizes
- QRST changes
Case 1

A 62 year old female with Type 2 diabetes mellitus presents with diaphoresis
Case 1: Rate

- Rate: is the rhythm regular or irregular?
- Answer: irregular
- How do you determine rate?
Rate with Regular Rhythm

• The 300 – 150 – 100 – 75 - 60 – 50 – 43 – 37 - 33 “rule”
Rate with Irregular Rhythm

- For irregular rhythms, check the EKG’s 3 second markers (15 large boxes). Count the complexes beginning with zero within a 30 large boxes (6 seconds) and multiply by 10 = avg # beats/60 sec. or estimated beats per minute.

Ex: In the above ECG, the rhythm is irregular. No of R-R intervals in 30 large boxes are 11. So heart rate is 11x10 = 110bpm.

30 large boxes
(6 seconds)
Case 1: Rate
Case 1: Rhythm

- Rhythm is irregular but...
- Are there p waves?
  - Yes
- Are the p waves upright in lead II?
  - Yes
- Are the p waves regular or irregular?
  - Regular
- Is this sinus rhythm?
  - Yes (we’ll get back to this)
- Next determine the QRS axis
QRS Axis

To determine the mean frontal axis, first identify the isoelectric lead — the lead with equal R and S waves. This represents the vector perpendicular to the mean axis. Next, identify the lead that is most positive (tallest R waves) which indicates the closest vector to the mean axis.

For example, if the isoelectric lead is aVL (-30°) the mean axis could be either 60° or -120°. If lead II is all positive the mean axis is 60°. If aVR is primarily positive, (and lead II negative) then the axis is -120°.
Let’s determine the QRS Axis.
Choose the *limb lead* where the QRS complex is closest to isoelectric and draw a yellow line. Draw a red line perpendicular to this line. This is on aVL. If the QRS on aVL is upright (positive), then axis = -30. If the QRS would have been downward (negative) then axis = +150.
QRS Axis

Our patient has a left axis deviation. What are causes of LAD?
Case 1

- Negative 30 to negative 90 degrees
- Mechanical shifts (elevated diaphragm)
- LBBB
- Left Anterior Fascicular Block or LAHB
- WPW syndrome (sometimes)
- Inferior wall MI
- Sometimes LVH
Case 1: Intervals

QRS duration: How many boxes is the QRS complex? It’s just under 3 boxes or 0.11 seconds.
Case 1: Intervals

- Normal QRS complex duration is 60 – 100 msec (1.5 to 2.5 small boxes)
- This patient’s is 110 msec
- Intermediate QRS is > 100 to < 120 msec seen with junctional beats, high ectopic ventricular beats, hemiblocks, electrolyte abnormalities (i.e. severe hyperkalemia) and with some medications (some antiarrhythmic agents)
- Ventricular beats or Bundle Branch Blocks ≥ 120 msec.
- This EKG rhythm is not considered wide complex, so while the QRS isn’t normal, it’s still categorized as a narrow complex (atrial or junctional) rhythm
- We have no labs or other history to help us on this patient
Case 1 Intervals

• What is her QTc interval?

• The normal QTc interval is considered to be from 360 msec to 450 msec in males and to 460 msec in females

• To calculate the QTc, first measure the QT interval. In this case the average QT is \( \sim 0.39 \) seconds.

• Then measure the average R-R interval. This one is 0.86 sec.

• Plug them into: 

\[
QTc = \frac{QT}{\sqrt{RR}}
\]

and this QTc is normal = 0.42 sec
Intervals

PR intervals: normal is 0.12 sec to 0.20 sec (3 to 5 small boxes)

Our patient’s PR intervals vary. PR interval variation can be seen with different atrial foci or due to AV nodal disease. (examples include PACs, WAP, MAT, 2nd Degree AV Block)

Our patient is in sinus rhythm (the same p wave morphology) with a 2nd Degree AV Block, Type 1 or Wenckebach
Atrioventricular Blocks

2nd Degree AV Block Type 1 (Wenckebach)

In classic Wenckebach, the PR interval gets longer until a nonconducted P wave occurs. The RR interval of the pause is shorter than the sum of the 2 preceding RR intervals, and the RR interval after the pause is longer than the RR interval before the pause.

The block is located in the AV node.
Case 1 summary EKG interpretation at this point

- Rate = 70 and irregular
- Rhythm = atrial is regular at < 100 bpm, narrow complex with positive p wave in lead II, c/w sinus rhythm
- With Wenckebach
- QRS axis = -30 or left axis deviation
- Intervals:
  - PR varies due to Wenckebach
  - QRS duration is 0.11 sec (intermediate)
  - QTc interval = 0.42 sec (normal)
- Chamber sizes (will be addressed in another case); they’re normal here
QRST Changes/Abnormalities

Are there any ST elevations? Leads II, III, aVF How many mm.?
Acute Myocardial Infarction

• ECG diagnosis requires at least 1 mm (0.1 mV) of new ST segment elevation in corresponding anatomical limb leads, V4, V5 or V6
• At least 2 mm elevation in males (1.5 mm in females) at the V2 and V3 J-point
• These elevations must be anatomically contiguous.
  • I, aVL, V5, V6 = lateral wall
  • V1, V2, and sometimes V3 = septal or anteroseptal wall
  • V3, V4 = apical or anteroapical wall
  • II, III, aVF = inferior wall
• True posterior MI pattern with ST depression in V1, V2, and sometimes V3
• New LBBB in suspicious setting
Our patient seems to be having an acute inferior wall infarct. Is that all?
QRST Changes/Abnormalities

Are there any ST depressions? Leads 1, aVL and V2-3; maybe upsloping in V1
Reciprocal Changes

• The inferior wall infarct (II, III, aVF) does not have true reciprocal leads, but...

• If the infarct extends posteriorly (inferior-posterior infarct), ST depressions can occur in the anteroseptal (V1, V2 and sometimes V3) and high lateral leads (I, aVL)

• This occurs in our patient which helps solidify the diagnosis of an acute inferior-posterior infarct
Reciprocal Changes

• Acute anteroseptal infarctions (V1, V2, V3) may show reciprocal lateral changes in V5, V6, I, and/or aVL.

• A left lateral wall infarct (V5, V6, I, aVL) may show reciprocal changes in aVR, and sometimes V1 and V2 (depending on lead placement and how lateral the infarction is).

• A right sided infarct (rV4, aVR) may show reciprocal changes to the left lateral leads (V5, V6, I, aVL).
Case 1 EKG Final Interpretation

• Atrial rhythm is probably sinus at a rate of 90 to 100 bpm with an irregular average ventricular rate of 70 bpm
• Irregular ventricular rate is due to 2nd Degree AV block Type 1 or Wenckebach
• Left axis deviation (-30 degrees)
• QRS duration is 0.11 sec (intermediate)
• QTc interval = 0.42 sec (normal)
• Chamber sizes are normal
• The 2nd degree Type 1 AV block (Wenckebach) and the left axis deviation are due to an acute inferior-posterior wall infarction with reciprocal changes seen in leads I, aVL, (V1) V2 and V3
Case 2

59 year old male smoker with hypertension on lisinopril with substernal chest pain and mild shortness of breath for the past 30 minutes
Case 2: Rate

- Rate: is the rhythm regular or irregular?
- Answer: irregular
- How do you determine rate for an irregular rhythm?

Rate = 70 and irregular
Case 2: Rhythm

- Rhythm is irregular
- Is it narrow or wide complex?
  - Narrow
- Name some narrow complex irregular atrial rhythms:
  - Wandering atrial pacemaker
  - Sinus arrhythmia
  - Multifocal atrial tachycardia
  - Atrial flutter with variable block
  - Sinus rhythm with PACs or PJBs
  - Atrial fibrillation
- Are there p waves?
  - No
- Atrial fibrillation (coarse and fine)
  - Coarse atrial fibrillation
Case 2: QRS Axis

• QRS Axis: Choose the limb lead where the QRS complex is closest to isoelectric and draw a yellow line.

QRS Axis: Draw a red line perpendicular to this line. This is on lead I.

If the QRS on I is upright (positive), then axis = 0 which is normal.

If the QRS would have been downward (negative) then axis = +180.
Case 2: Intervals

- PR interval is?
- Cannot calculate because there are no true p waves
- QRS duration is 100 msec (is upper limit of normal but normal)
- QTc interval = 0.41 sec
Case 2: Chambers

- Cannot determine LAE or RAE because we need to measure p waves (and there are no p waves in atrial fibrillation)
- Are any ventricles enlarged?
- Criteria for LVH
Sokolow-Lyon Indices:
S wave in V1 + R wave in V5 or in V6 = 35 mm or more OR
R wave in aVL > 11 mm

Cornell Voltage Criteria:
S wave in V3 + R wave in aVL > 28 mm in males and > 20 mm in females

Supporting evidence includes left axis deviation and widened QRS/T angle usually seen in leads V5 and V6 (called LV strain pattern)
Case 2 summary EKG interpretation at this point

- Rate = 70 and irregular
- Rhythm = coarse atrial fibrillation
- QRS axis = 0 degrees (normal)
- PR interval cannot calculate
- QRS duration is 0.10 sec (normal)
- QTc interval = 0.41 sec (normal)
- Chamber sizes: LVH
Let’s look at ST segments and T waves

ST depressions and T wave inversions in leads I and aVL

Is this finding old or new?  New

LVH-related depolarization variant is usually not seen in leads I and AVL. These could represent lateral ischemia or reciprocal changes.

Biphasic T waves seen in leads V2, V3 and V4 are Wellen’s waves seen with a tight proximal LAD stenosis
Wellens syndrome or LAD coronary T-wave syndrome.
Criteria include:
Characteristic T-wave changes
History of anginal chest pain
Normal or minimally elevated cardiac enzyme levels
ECG without Q waves or significant ST elevation; normal precordial R-wave progression.

The common form shows deep T wave inversion in precordial leads.
The ST segment will be straight or concave, and pass into a deep negative T wave at an angle of 60-90 degrees. The T wave is symmetric. These changes generally occur in leads V₁ - V₄ but may occasionally involve V₅ and V₆.
The less common variant of Wellens syndrome (24% of patients) consists of biphasic T waves, most commonly in leads V₂ and V₃, but also can include V₁, V₅/V₆.
Case 2 summary EKG interpretation

- Rate = 70 and irregular
- Rhythm = coarse atrial fibrillation
- QRS axis = 0 degrees (normal)
- PR interval cannot calculate
- QRS duration is 0.10 sec (normal)
- QTc interval = 0.41 sec (normal)
- Chamber sizes: LVH
- Acute anteroseptal/apical infarction c/w Wellen’s Syndrome
Case 3: 51 year old complains of palpitations. What is the rhythm? Are there P waves?
Case 3: AV Nodal Re-entrant Tachycardia

No definite p waves seen before the QRS, rate ~ 150 to 200 and very regular.
May see retrograde p waves (seen as pseudo-terminal S waves in leads II & aVF, and pseudo-r’ in V1)
Case 4: 42 year old male with sharp substernal chest pain

What is your diagnosis and why?
Are the ST segment and T wave abnormalities distributed in anatomical leads?
Case 4: Acute Pericarditis
Case 5: This patient is asymptomatic and had a Welcome to Medicare exam. Comment on the conduction system abnormalities?
Right Bundle Branch Block

Complete RBBB has a widened QRS > 0.12 sec. Terminal forces (2nd half of QRS) are oriented rightward and anteriorly toward V1 and V2 (positive deflections) because the RV is depolarized after the LV. The terminal negative deflection in V6 (wide S wave) represents RV depolarization.
Left Anterior Fascicular Block

When isolated LAFB, QRS duration < 0.12 sec
Left Axis Deviation (usually < -35 degrees)
Small Q waves in leads I and aVL; S > R waves in leads II, III, and aVF
Sometimes a deep S wave in V6
Case 5: Bifascicular Block with Right Bundle Branch Block & Left Anterior Fascicular Block

QRS Axis < -35
Case 6: 68 y.o. w/ dyspnea.
Let’s interpret the EKG.

Rate 60 & irregular  Rhythm ?
QRS 110 ms  QRS 110 ms
QTc 430 ms  QTc 430 ms
PR ?  PR ?

Atrial flutter with variable block
Inferior Q waves & poor R wave progression, c/w inferior and anterior infarcts, age undetermined
Lateral T wave inversions

Axis -70
Left Axis Deviation etiologies:
Mechanical shift (elevated diaphragm)
LBBB; LAFB; sometimes WPW;
Inferior wall MI; sometimes LVH
Case 6: Atrial Flutter with Variable AV Block

Regular rapid P-waves at a rate of ~200

Irregular R-R intervals
Case 7: 59 y.o. smoker w/ worsening cough and wheeze. Let's interpret this EKG.

Rate 140 & irregular
Rhythm ? (we’ll review on next slide)
Axis +88
QRS 93 ms
QTc 450 ms
PR ?
Poor R wave progression V1– 4 c/w anteroseptal infarct, age undetermined
Lateral T wave inversions
Case 7: Multifocal Atrial Tachycardia

P-waves of at least 3 morphologies
Case 8: 41 y.o. has been intermittently feeling very lightheaded. Does anything appear unusual on this EKG?

Rate = 64 bpm  
Rhythm = NSR @ 76  
Axis = + 58 degrees  
PR = 0.18 sec  
QRS = 0.11 sec  
QTc = 0.42  
Segments?  
Bundles? QRS?  
V1-2-3 RBBB pattern  
“cove” pattern often with a  
1st degree AVB (not in this case)  
Brugada Syndrome Type 1
Case 8: **Brugada Syndrome** recognized in 1988 and described in 1992 is a genetic **sodium channel defect** that leads to V fib. Worsened by Class 1C antiarrhythmics (i.e., flecanide) and vagal maneuvers.

ECG abnormality **must** be associated with one **clinical criteria** to make the diagnosis:
- Documented ventricular fibrillation or polymorphic ventricular tachycardia
- Family history of sudden cardiac death at <45 years old
- Coved-type ECGs in family members
- Inducible VT with programmed electrical stimulation
- Syncope or Nocturnal agonal respirations
Brugada Syndrome Type 2
Case 9: 18 y.o running track returns to the gym and he and a friend decide to play with a trainer’s EKG machine.

Ventricular rate = 112 bpm  
Sinus tachycardia  
PR interval = 178 ms  
QRS duration = 112 ms  
QT/QTc = 328/452 ms  
Axis = + 68 degrees

Incomplete RBBB
Rsr’ in V1
QRS duration 101 - 119 msec
T wave inversions in leads V1-2-3 can be normal in Incomplete RBBB

Should this student be disqualified from running track?
Case 9: Seattle Criteria for Normal EKG Findings in Athletes

- Sinus bradycardia (>30 bpm)
- Sinus arrhythmia
- Ectopic atrial rhythm
- Junctional escape rhythm
- Mobitz Type I (Wenckebach) 2\textsuperscript{nd} degree AV block
- Incomplete RBBB
- Isolated QRS voltage criteria for LVH (no LAE, LAD, ST depression, T wave inversions, or pathological Q waves)
- Early repolarization (J point elevation)
- Convex ("domed") ST segment elevation w/ T wave inversion leads V1-4 in AA athletes
Case 10: This patient is new to your practice and sends ahead his records which include this EKG that’s not interpreted.

Ventricular rate = 112 bpm
Rhythm = Sinus tachycardia
PR interval = 190 ms
QRS duration = 101 ms
QT/QTc = 412/443 ms
Axis = + 120 degrees

Right Axis Deviation etiologies:
- Mechanical shifts (emphysema)
- RBBB
- RVH
- LPFB
- WPW syndrome (some)
- Dextrocardia
- Lateral wall MI
- Acute right heart strain (large PE)

Left Posterior Fascicular Block
Poor R wave progression V2 – V4 c/w old anterior infarct

S > R wave in I & AVL  
No RVH

Small Q in II, III, AVF  
Axis ~ +120

QRS <0.12
Positive or negative concordance throughout chest leads (i.e. leads V1-6 show entirely positive R complexes or entirely negative QS complexes), with no RS complexes seen, favors V-tach; lack of concordance (RS complexes) favors SVT w/ aberrancy.

Leads V2-3 have rSR' pattern which favors SVT with aberrancy (RSr' would favor V-tach).

Is this rhythm an aberrantly conducted SVT or ventricular tachycardia?

Case 11: 51 year old female feels palpitations and lightheadedness.

Rate = 180 bpm
QRS = 0.15 sec
Rhythm = ?

Positive or negative concordance throughout chest leads (i.e. leads V1-6 show entirely positive R complexes or entirely negative QS complexes), with no RS complexes seen, favors V-tach; lack of concordance (RS complexes) favors SVT w/ aberrancy.
Case 11: Wide Complex Tachycardia

- EKG differentiation of VT from SVT with aberrancy is not always possible, some features favoring VT include:
  - AV dissociation (identify P and QRS complexes at different rates)
  - Capture beats - the SA node transiently ‘captures’ the ventricles, in the midst of AV dissociation, to produce a QRS complex of normal duration
• Fusion beats - when a sinus and ventricular beat coincide to produce a hybrid complex

• Brugada’s sign - distance from the onset of the QRS complex to the nadir of the S wave is > 100ms

• Josephson’s sign - notching near the nadir of the S wave
• RSr’ complexes with a taller left rabbit ear strongly favor of VT

• In contrast to RBBB and SVT with aberrancy, where the right rabbit ear is taller (rSR’

[Images of ECG tracings showing taller left and right rabbit ears in VT and RBBB respectively]
Brugada criteria:
Is there absence of RS complex in all V1-V6 leads? If Yes, V-tach. If No, is an RS complex > 100 ms in any? If Yes, V-tach. RSR’ (seen in V4) would favor V-tach
Josephson’s sign seen in aVL

Is this V-tach or SVT with aberrancy?
Case 12: 53 y.o. male with hyperlipidemia, hypertension and smoking presents with left jaw pain. Is he having an infarct? If so, where?

Anteroseptal MI with lateral lead reciprocal changes
Rate: 62
Rhythm: Sinus with PAC
Axis: -45 (mechanical shift, LBBB, LAFB, sometimes WPW, inferior wall MI, sometimes LVH)
PR: 110 msec
QRS: 106 msec
QTc: 395 msec
Delta waves, intraventricular conduction delay
Case 13: Wolff-Parkinson-White Syndrome

An absent or difficult to see negative delta wave in V1, and S > R in V1 indicates a right sided insertion of accessory pathway; A positive delta wave in V1 and R > S in V1 indicates left sided insertion.
Case 14: What is the rhythm?

Sinus rhythm with third degree heart block
Case 15: Which two chambers are enlarged?

Right Ventricle and Right Atrium

- Tall R Wave in V1 = Mechanical shifts; Posterior MI; WPW syndrome; Dextrocardia; Right Ventricular Hypertrophy; Right Bundle Branch Block; Lateral Wall MI
- Acute Right Heart Strain; Children under age 2

- Lead II p > 2.5 mm tall
- Negative QRS in Lead 1
- Positive QRS in Lead V1
- May see RV strain in V1-2-3
- Axis = +210 degrees
- May have deep S wave in V5 and V6

Tall R Wave in V1 = Mechanical shifts; Posterior MI; WPW syndrome; Dextrocardia; Right Ventricular Hypertrophy; Right Bundle Branch Block; Lateral Wall MI
Acute Right Heart Strain; Children under age 2
References

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Thank You